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WING SWEEP AND BLUNTING EFFECTS ON  
DELTA PLANFORMS AT  $M = 20$

by

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# Nomenclature

$C_D$	drag coefficient $\frac{D}{qS}$
$C_{pmax}$	maximum pressure coefficient
$C_L$	lift coefficient $\frac{L}{qS}$
$C_{L\alpha}$	lift curve slope at $\alpha = 0^\circ$ , per deg
$d$	wing leading edge diameter, inches [figure 1(a)]
$d/l$	wing thickness ratio
$D$	drag, pounds
$l$	wing length, inches [figure 1(a)]
$L$	lift, pounds
$L/D$	lift-drag ratio, $\frac{C_L}{C_D}$
$M_\infty$	free stream Mach number
$q$	dynamic pressure, pounds per square inch
$r$	leading edge radius, inches
$S$	wing planform area, square inches
alpha	$\alpha$ angle of attack
lambda	$\Lambda$ sweep angle, degrees [figure 1(a)]
gamma	$\gamma$ ratio of specific heats

~~The advantage in the ability of hypervelocity vehicles to develop lifting capabilities has been recognized for some time. When considering lifting bodies, the basic delta planform is a type which is often considered. Leading edge blunting and sweep angle are prime factors affecting the performance parameters of delta planforms.~~ This paper is a brief resume' of the preliminary results obtained from an investigation recently conducted at a Mach number of 20 in helium flow to determine the effects of leading edge blunting and sweep angle on the static longitudinal stability characteristics of basic delta planforms, with particular emphasis on maximum lift-drag ratio. For the purpose of brevity only summary plots are presented.

The experimental results were obtained in the Langley 22-inch helium tunnel utilizing a contoured nozzle to obtain a uniform free stream Mach number of  $20.3^1$ . Stagnation temperature for the tests was approximately  $80^\circ\text{F}$ . Reynolds number, based on chord length, ranged from  $1.5 \times 10^6$  to  $5.5 \times 10^6$ , but for wings having thickness ratios less than .034, a constant Reynolds number of  $3.7 \times 10^6$  was maintained in order to minimize any possible Reynolds number effects. A wing having a thickness ratio of 0.01 and sweep angle of  $80^\circ$  was tested at Reynolds number of both  $3.7 \times 10^6$  and  $6.6 \times 10^6$  and this difference in Reynolds number yielded

no appreciable difference in  $L/D_{\max}$ . Angle of attack was limited to a  $0^\circ$  to  $30^\circ$  range, and wind tunnel blockage, caused by the relatively large size of some of the models, did not permit all models to reach  $30^\circ$  angle of attack. The models used in the present investigation were hemispherically and hemiscylindrically blunted delta planforms and the ratio of leading edge diameter to body length varied from 0 to 0.3. The sweep angles considered were  $45^\circ$ ,  $60^\circ$ ,  $70^\circ$ ,  $80^\circ$ ,  $85^\circ$  and  $90^\circ$ . A sketch of the basic delta planform models used is shown in figure 1(a) and the accompanying table indicates the pertinent dimensions, including the presence of a balance housing body, which became necessary on the more slender configurations. Figure 1(b) contains a sketch of the models used to simulate zero leading edge thickness, and the balance housing body associated with the models. In order to shed some light on the effect of the presence of the balance housing bodies, the wing with a  $80^\circ$  sweep angle and thickness ratio of 0.01 was tested using the balance housing body from the wings shown in figure 1(b). The base of this body was located 0.3 inches from the base of the wing.

The maximum lift-drag ratios obtained in the investigation are shown in figure 2 as a function of thickness ratio, the flagged symbols denoting wings which had balance housing bodies. As previously mentioned, the wing having an  $80^\circ$

sweep angle and thickness ratio of 0.01 was tested with the smaller balance housing body shown in figure 1(a) (the smaller body had about 18% as much volume as the large balance housing body), and this resulted in only a 3% increase in  $L/D_{\max}$ , which is believed to be well within the accuracy of the data. Note the near exponential increase in lift-drag ratio that occurs when thickness ratio decreases. For the more slender wings, the models with  $80^\circ$  sweep angles obtained the higher values of  $L/D_{\max}$  for a particular thickness ratio. Optimum sweep angle is more readily obtained from figure 3, which indicates that as thickness ratio increased from a value of zero the optimum sweep angle for maximum lift-drag ratio decreased from an angle of  $80^\circ$  or slightly larger, to  $70^\circ$  or less for the more blunt shapes tested. The peak in  $L/D_{\max}$  for each constant bluntness curve suggests that as sweep decreases from  $90^\circ$ , the increased lifting surface more than offsets the increase in drag initially; while at sweep angles less than optimum the converse is true. Unfortunately, the angle of attack range did not permit many of the more blunt wings to obtain a maximum lift-drag ratio and the optimum sweep angle for the more blunt bodies could not be definitely ascertained. Newtonian theory, which is shown as calculated, neglecting viscous effects, for wings without bodies<sup>2</sup>, is seen in figure 2 to give good prediction

of maximum lift-drag ratio for the thickest wings and is useful in determining the optimum sweep angle for these wings (\*solid symbols on figure 3).

alpha  $C_{L\alpha}$  was found to vary linearly or near linearly with thickness ratio as shown in figure 4. As sweep angle  
alpha increased,  $C_{L\alpha}$  was seen to decrease, a trend previously obtained on slender wings at lower hypersonic speeds<sup>3</sup>. Because the presence of balance housing bodies would tend to introduce negative lift at and near zero degrees angle of attack, the only values of  
alpha  $C_{L\alpha}$  presented are those for wings which had no balance housing bodies, which were the more blunt wings. Within the limitation  
alpha of the data in figure 4, values of  $C_{L\alpha}$  for arbitrary combination of thickness ratio and sweep angle may easily be interpolated.

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\* As a point of interest, Newtonian theory in a modified form, was used, applying a stagnation pressure coefficient  
gamma given by  $\left( \frac{\gamma + 3}{\gamma + 1} \right) \left( 1 - \left( \frac{2}{\gamma + 3} \right) \left( \frac{1}{M^2} \right) \right)$  on the  
gamma cylindrical leading edge section and the spherical segment nose sections and applying  $(\gamma + 1)$  to the flat plate portion of the wings, but it was found that classical Newtonian theory ( $C_{p_{max}} = 2$ ) generally gave better predictions of all forces and moments.

Of primary concern, of course, is the marked effect of even small degrees of leading edge blunting on  $L/D_{\max}$ . It is clear then that the achievement of high  $L/D_{\max}$  during re-entry (of as much as 4 or more, say) for practical configurations will require the application of much effort and ingenuity on the part of designers.

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#### FIGURE TITLES

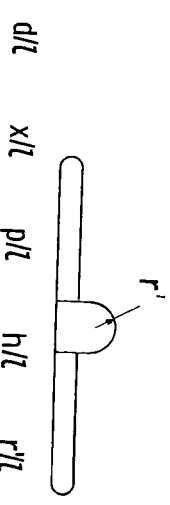
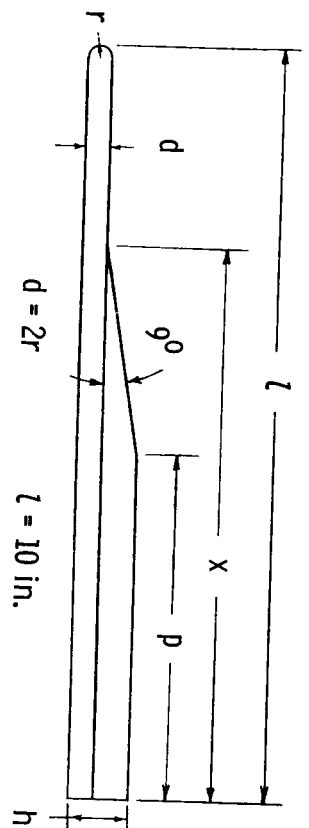
Figure 1(a). - Sketch of wings having balance housing bodies.

Figure 1(b). - Sketch of wings used to simulate zero leading-edge radius.

Figure 2. - Effect of thickness ratio on  $L/D_{\max}$ .

Figure 3. - Optimum sweep angle for  $L/D_{\max}$ .

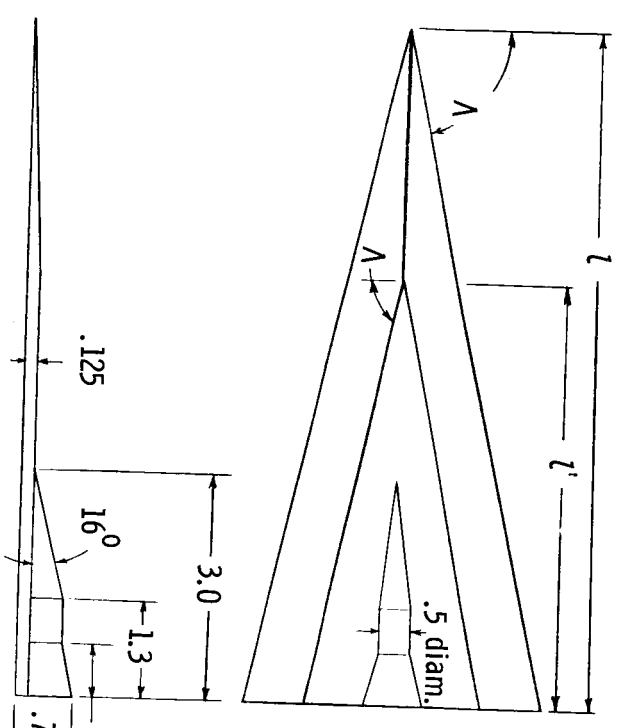
Figure 4. - Effect of wing sweep and thickness on  $C_{L\alpha}$ .



for  $d/l > .08$ ,  $h = d$

$d/l$	$x/l$	$p/l$	$h/l$	$r'/l$
0.01	0.88	0.46	0.08	0.037
.02	.84	.46	.08	.037
.033	.75	.51	.07	.035

Figure 1(a). - Sketch of wings having balance housing bodies.



$\Lambda$	$l'/l$	$l$
85°	0.77	11.38
80°	.65	11.34
70°	.77	8.15
60°	.77	5.20

$r/l = 0$

Figure 1(b). - Sketch of wings used to simulate zero leading-edge radius.

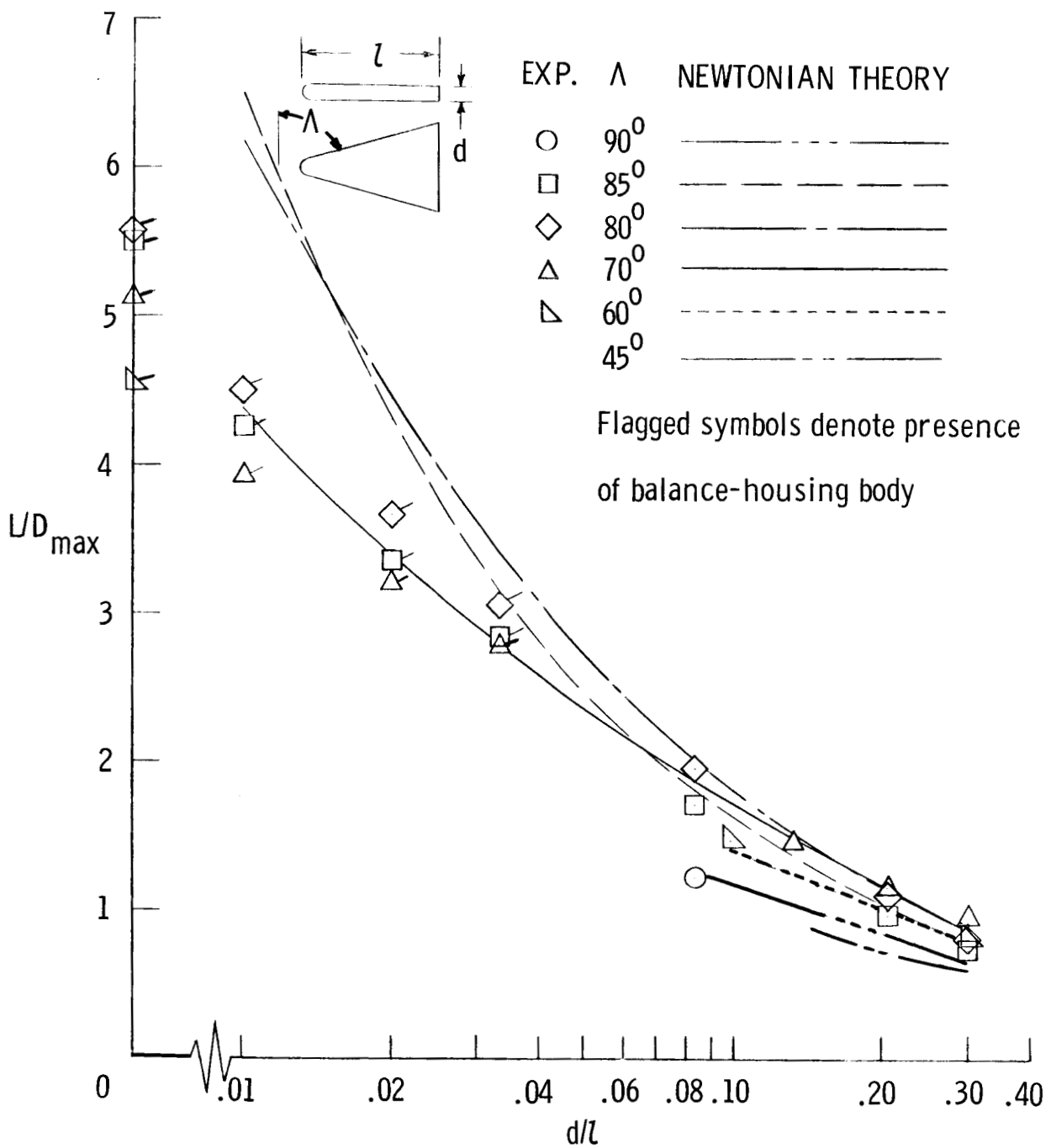


Figure 2. - Effect of thickness ratio on  $L/D_{\max}$ .

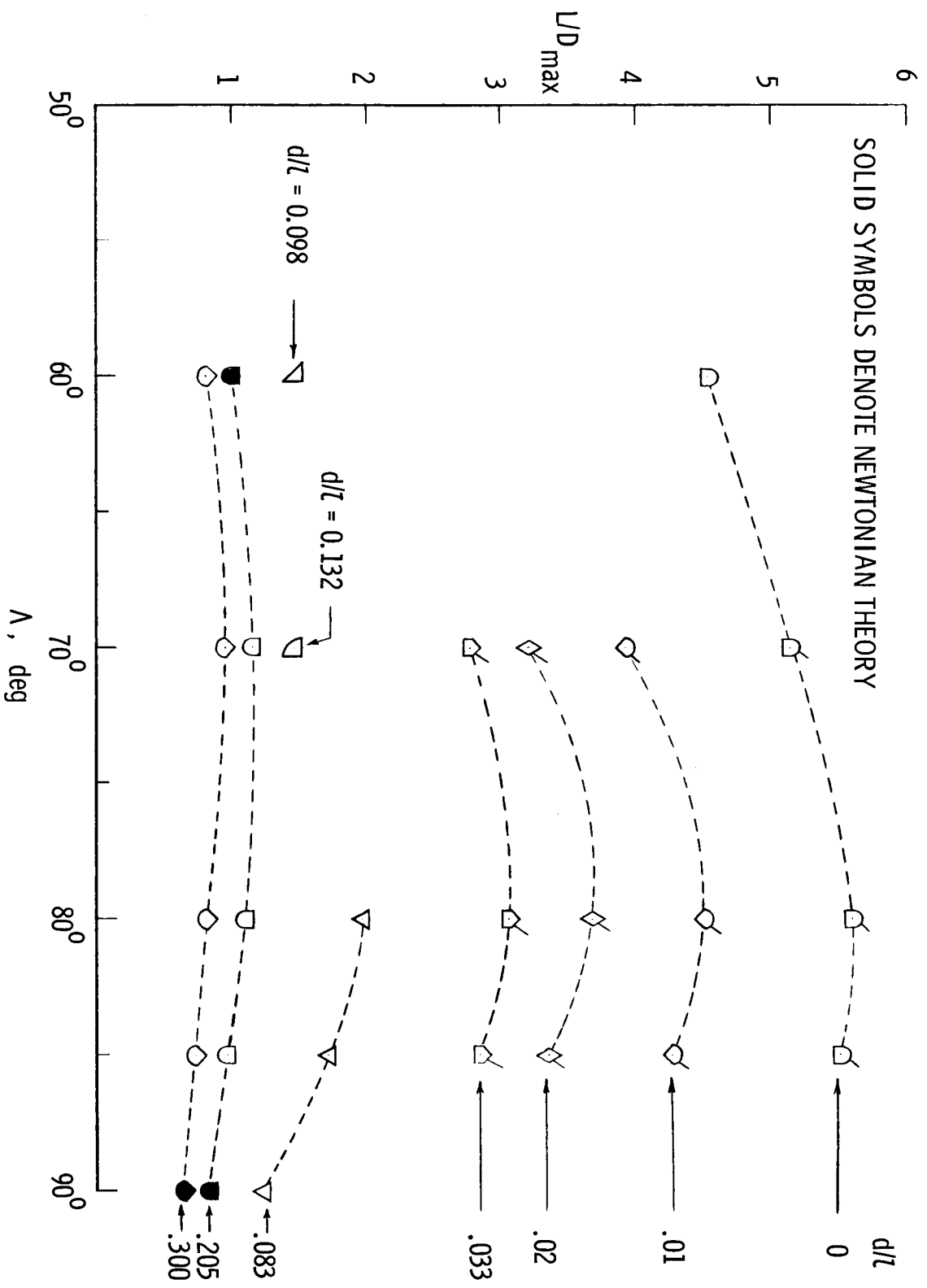


Figure 3. - Optimum sweep angle for  $L/D_{max}$ .

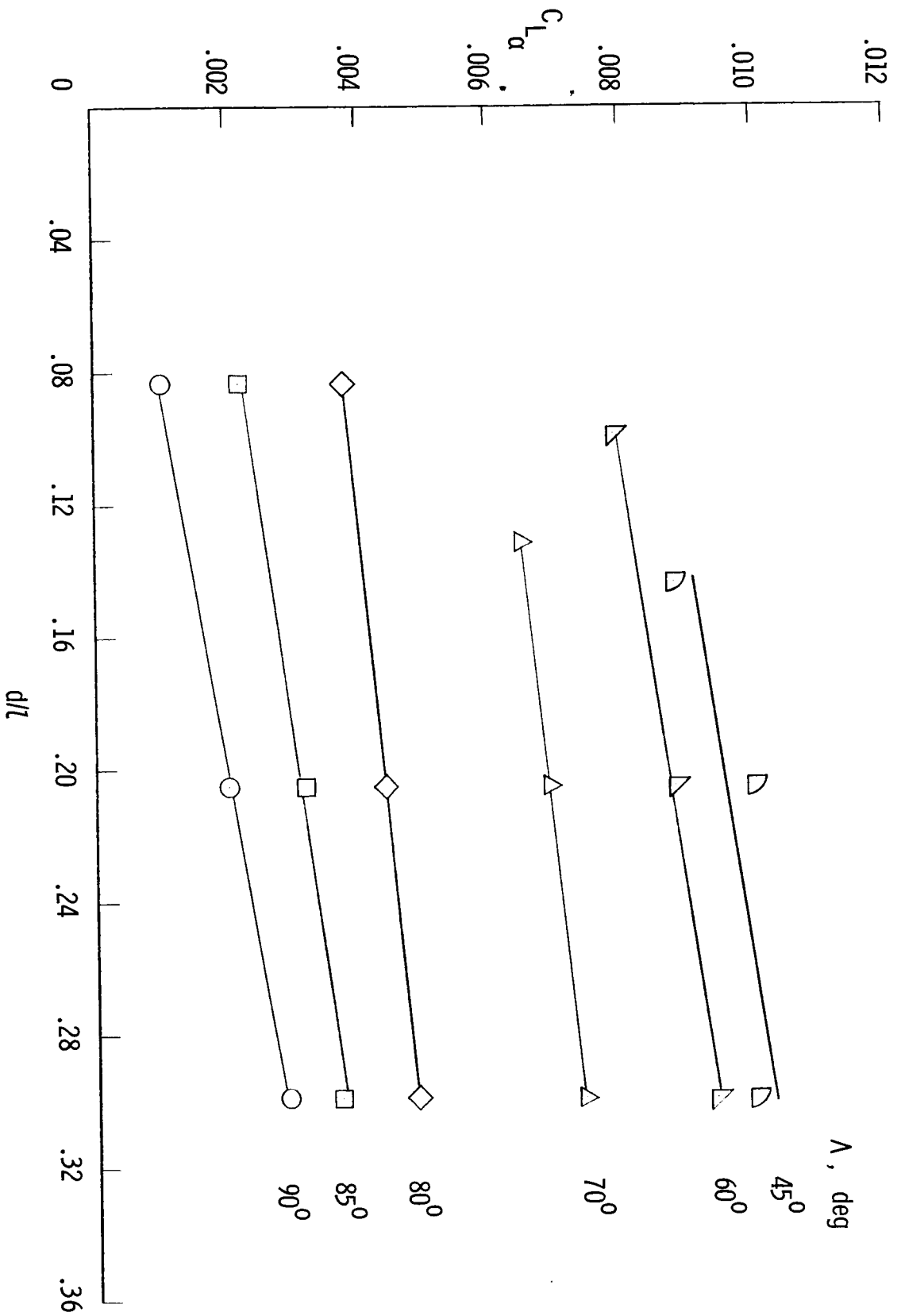


Figure 4. - Effect of wing sweep and thickness on  $C_{L_\alpha}$ .